Final Report for Contract 6850A from NASA Goddard Space Flight Center

Title: Observational Analysis and Theoretical Modeling Investigations of Dynamics for UARS

During the 5 1/2 years of this contract, we executed the following tasks in support of the UARS objectives.

(1) M. Geller chaired the group that was in charge of validating the UARS wind measurements of the UARS HRDI and WINDII instruments.

(2) We acted as UARS Science Team liaisons for the following UARS Correlative Investigators: Dr. David Fritts, Dr. Steven Smith, and Dr. Robert deZafra.

(3) We performed UARS-relevant scientific research both before and after the launch of UARS.

In the following, we will briefly describe our efforts in these three areas.

UARS Dynamics Validation

M. A. Geller served as the chair of the UARS Dynamics validation group. In this capacity, he helped develop (along with P. Hays and G. Shepherd) the correlative measurements requirements for the HRDI and WINDII wind measurements. Geller's research group also engaged in the verification efforts for the HRDI MLT winds. There was considerable delay in the HRDI stratospheric wind and the WINDII wind products becoming available. A paper giving some of the results of our efforts on this appeared in the UARS validation *JGR* issue.

A number of UARS Dynamics workshops were organized, in which M. A. Geller played a key organizational role. When it became clear that there were significant disagreements between UARS wind measurements and MF radar measurements above about 85 km altitude, two Winds Workshops were organized. A key goal of this effort was to characterize and understand the middle atmosphere wind measurement biases of existing methods.

Science Team Liaisons

We were the UARS Science Team liaisons for three UARS Correlative Investigators. These were Dr. David Fritts, who supplied MF radar data from Kauai, Hawaii; Dr. Steve Smith, who supplied MST radar data from Huntsville, Alabama; and Dr. Robert deZafra who supplied ClO measurements from his ground-based mm-wave measurements. In this regard, we put these correlative measurements into the CDHF and supplied the Correlative Investigators with UARS data when these were requested.

Science Investigations

Dr. Fumio Hasebe was supported by this contract for two years. During that time, he did a lot of software preparation for the validation of the HRDI stratospheric winds. Unfortunately, these data were never available during the time he was at Stony Brook. He also developed statistical procedures to compare measurements made by different techniques. This work has been presented at meetings but has never been published. Dr. Hasebe also did research using TOMS O_3. These are contained in the following two papers.

Hasebe, F., 1993: Dynamical Response of the Tropical Total Ozone to Sea Surface Temperature Changes. *J. Atmos. Sci., 50*, 345-356.

In this paper, it was illustrated that interannual variations in equatorial total ozone arise through two different processes. One is a symmetric change that is the result of changes in the tropical upwelling circulation. The other is an asymmetric change that is the result of the longitudinal variation of the tropical tropopause.

Hasebe, F., 1994: Quasi-Biennial Oscillations of Ozone and Diabatic Circulation in the Equatorial Stratosphere. *J. Atmos. Sci., 51*, 729-745.

In this paper, SAGE ozone data was analyzed for the period 1984-1989. A mechanistic model was shown to be able to produce the QBO in ozone, and the important feedback effect of the changed radiative heating on the QBO variation of ozone was discussed. The suggestion was made that more sophisticated models were needed to allow for the full dynamical-chemical-radiative feedback processes.

Also, in preparation for the launch of UARS, some research was undertaken to show the effects of satellite observation and mapping on the

Geller, M. A., Y. Chi, R. B. Rood, A. R. Douglass, D. J. Allen, M. Cerniglia, and J. W. Waters, 1993: 3-D Transport-Chemistry Studies of the Stratosphere Using Satellite Data Together with Data Assimilation. In *Impact of the Stratosphere on Climate and the Biosphere*, M. I. Chanin (ed.), Kluwer Press, 179-198.

This paper describes the general research philosophy of how to use CTM's together with data assimilation to interpret satellite data. It gives examples of the nature shown in the Douglass et al., 1993, paper.

Geller, M. A., V. Yudin, A. R. Douglass, J. W. Waters, L. S. Elson, A. E. Roche, and J. M. Russell III, 1995: UARS PSC, $ClONO_2$, HCl, and ClO Measurements in early Winter: Additional Evidence for the Paradigm for Chlorine Activation. *Geophys. Res. Lett.*, 22, 2937-2940.

This paper shows UARS measured decreases in $ClONO_2$ and HCl coinciding with the presence of PSCs, with the implied polar processing, and increasing ClO. Although, the paradigm for polar processing has been accepted on the basis of aircraft measurements of HCl and ClO as well as theory, this was the first time that the behavior of these three crucial chlorine species has been measured simultaneously in the same air mass.

Yudin, V. A., M. A. Geller, B. V. Khattatov, A. R. Douglass, M. C. Cerniglia, J. W. Waters, L. S. Elson, A. E. Roche, and J. M. Russell III, 1996: The Early Stages of Lower Stratospheric Polar Processing in Northern and Southern Winters: Model Results and UARS Observations. Submitted to *J. Geophys. Res.*

This paper gives a more complete picture of the progress of the polar processing of chlorine during 2 Northern and Southern Hemisphere in the early winter. It presents the time scales for the filling of the polar vortex with polar processed air and integrates the observations of PSCs (by their spectral signature), with depletions in $ClONO_2$ and HCl, and enhancements in ClO.

Another theme of our research was to use HRDI and WINDII wind data to gain a better understanding of the Mesosphere-Lower Thermosphere (MLT) region of the atmosphere.

Khattatov, B, M. Geller, V. Yudin, P. Hays, W. Skinner, M. Burrage, S. Franke, D. Fritts, J. Isler, A. Manson, C. Meek, R. McMurray, W. Singer, P. Hoffmann, and R. Vincent, 1996: Dynamics of the Mesosphere and Lower

Thermosphere as Seen by MF Radars and by HRDI/UARS. *J. Geophys. Res.*, *101*, 10,393-10,404.

It was shown that there was a systematic underestimate in MF radar measured wind above about 85 km relative to those measured by UARS/HRDI. The nonmigrating tidal amplitudes were estimated, and upper limits were given for planetary wave amplitudes.

Khattatov, B. V., M. A. Geller, V. A. Yudin, P. B. Hays, and R. A. Vincent, 1996: Diurnal Migrating Tide as Seen by HRDI/UARS. Part 1. Monthly Mean Global Meridional Winds. To appear in *J. Geophys. Res.*

In this paper, HRDI measurements of the meridional velocity component in the MLT region are used together with the governing tidal equations to provide a best analysis of the mean diurnal tidal structure of the meridional velocity component in this region.

Khattatov, B. V., V. A. Yudin, M. A. Geller, and P. B. Hays, 1996: Diurnal Migrating Tide as Seen by HRDI/UARS. Part 2. Monthly Mean Global Zonal and Vertical Velocities, Pressure, and Temperature, and Inferred Dissipation. To appear in *J. Geophys. Res.*

In this paper, the results of the previous paper are used, together with the governing equations, in an iterative scheme to find the remaining diurnal tidal variables(u, w, T, p). The tidal energy equation is then used to derive the atmospheric dissipation that is consistent with the derived tidal structures.

Khattatov, B. V., 1995: Dynamics of the mesosphere and Lower Thermosphere as Seen by MF Radars and by HRDI/UARS. Ph. D. Dissertation, State University of New York at Stony Brook, 113 pages.

This Ph. D. dissertation by Khattatov developed the methodology and derived the results of the previous three papers.

Several more papers are in preparation or have been submitted. These will be reported in the annual report of the new UARS grant.

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